Diuron Criteria Derivation
DRAFT

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1. Introduction

An updated methodology for deriving freshwater water quality criteria for the protection of aquatic life was developed (TenBrook *et al.* 2009a). The need for a new methodology was identified by the California Central Valley Regional Water Quality Control Board (CVRWQCB 2006) and findings from a review of existing methodologies (TenBrook & Tjeerdema 2006, TenBrook *et al.* 2009b). This new methodology is currently being used to derive criteria for several pesticides of concern in the Sacramento River watershed. The methodology report contains an introduction, (Chapter 1); the rationale of the selection of specific methods (Chapter 2); detailed procedure for criteria derivation (Chapter 3); and a chlorpyrifos criteria report (Chapter 4). This criteria report for diuron describes, section by section, the procedures used. Also included are references to specific sections of the methodology procedure detailed in Chapter 3 of the report so that the reader can refer to the report for further details (TenBrook *et al.* 2009a).

2. Basic information

Chemical: Diuron (Fig. 1)
CAS: N'-(3,4-dichlorophenyl)-N,N-dimethylurea
IUPAC: 3-(3,4-dichlorophenyl)-1,1-dimethylurea
Chemical Formula: $C_9H_{10}Cl_2N_2O$

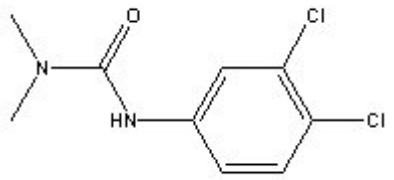

Figure 1. Structure of Diuron (source: http://sitem.herts.ac.uk/aeru/footprint/structure/260.jpg)

Trade names: AF 101, Cekiuron, Crisuron, Dailon, DCMU, Di-on, Diater, Dichlorofonidim, Direx, Diurex, Diurol, Diuron, Drexel, Dynex, Herbatox, Karmex, Krovar, Marmer, NA 2767, Telvar, Unidron, Urox D, Vonduron (Mackay *et al.* 2006).

CAS Number: 330-54-1
USEPA PC Code: 035505

CA DPR Chem Code: 231

3. Physical-chemical data

Molecular Weight
233.10 (ExToxNet 1996)

Density
1.5 g/mL (IUPAC 2008)

Water Solubility
42 mg/L at 25°C (Tomlin 1994)
35.6 mg/L at 20°C (IUPAC 2008)

Melting Point
158°C (Lide 2003)

Vapor Pressure
1.15 E -3 mPa at 25°C (IUPAC 2008)

Henry's constant (K_H)
1.5 x 10^{-4} Pa m^3 mol^{-1} (20-25°C, calculated-P/C) (Montgomery 1993; Mackay *et al.* 2006)
2.00 x 10^{-6} Pa m^3 mol^{-1} at 25°C (IUPAC 2008)
2.06 x 10^{-8} dimensionless at 20°C (IUPAC 2008)

Organic Carbon Sorption Partition Coefficients (log K_{oc})
All values and references from Mackay *et al.* (2006).

2.60 soil (Hamaker & Thompson 1972; Farmer 1976; Hance 1976)
2.59 average of 3 soils, HPLC-RT correlation (McCall *et al.* 1980)
2.21 soil, converted from reported K_{om} multiplied 1.724 (Briggs 1981)
2.58 average of 84 soils (Rao & Davidson 1982)
2.18 soil (Thomas 1982)
2.83 Webster soil (Nkedikizza *et al.* 1983)
2.49 soil slurry method (Swann *et al.* 1983)
2.48 RP-HPLC-RT correlation (Swann *et al.* 1983)
2.94 25°C, Semiahmoo soil, batch equilibrium method-LSS (Madhun *et al.* 1986)
2.68 25°C, Adkins soil, batch equilibrium method-LSS (Madhun *et al.* 1986)
2.58 soil, screening model calculations (Jury *et al.* 1987a; Jury *et al.* 1987b; Jury & Ghodrati 1989)
2.35 subsurface soil from Oklahoma (Bouchard & Wood 1988)
2.57 subsurface soil from Oklahoma (Bouchard & Wood 1988)
2.94 mucky peat soil, quoted (Howard 1991)
2.68 loam sand soil, quoted (Howard 1991)
2.68 soil, 20-25°C, selected (Wauchope *et al.* 1992; Hornsby *et al.* 1996)
2.40 soil (Sabljic *et al.* 1995)

2.44 soil, organic carbon OC ≥ 0.1%, average (Delle Site 2001)
2.43 soil, OC ≥ 0.5%, average (Delle Site 2001)
2.57 soil, 0.1 ≤ OC ≤ 0.5%, average (Delle Site 2001)
2.78 sediment, OC ≥ 0.5%, average (Delle Site 2001)
GeoMean of log K_{oc} values: 2.61

Log K_{ow}
2.68 recommended by Hansch (Hansch *et al.* 1995; Mackay *et al.* 2006)
2.78 recommended by Sangster Research Laboratories (2008)
2.87 at pH 7, 20°C (IUPAC 2008)

Bioconcentration Factor

Table 1. Bioconcentration factors (BCF) for diuron; FT: flow-through, SR: static renewal, S: static; values are on a wet weight basis and are not lipid-normalized.

Species	log BCF	Exposure	Reference
Gambusia affinis	2.46	S	Isensee 1976
Physa sp.	1.60	S	Isensee 1976
Daphnia magna	2.41	S	Isensee 1976
Oedogonium cardiacum	1.95	S	Isensee 1976
Pimephales promelas	2.00	S	Call *et al.* 1987

Environmental Fate

Table 2. Diuron hydrolysis and photolysis and other degradation. (NR: not reported).

	Half- life (d)	Water	Temp (°C)	pH	Reference
Hydrolysis	> 4 months	Phosphate buffer	20	5-9	Mackay *et al.* 2006
	Stable	Sterile buffer	25	5, 7, 9	USEPA 2003
Aqueous Photolysis	2.25 h	Distilled	NR	NR	Mackay *et al.* 2006
	43 d	NR	NR	NR	USEPA 2003
Biodegradation (aerobic)	~20 d	Filtered sewage water	20	NR	Mackay *et al.* 2006

4. Human and wildlife dietary values

There are no FDA action levels for diuron in food (USFDA 2000), but there is an EPA pesticide tolerance for farm-raised freshwater finfish tissue of 2.0 mg/kg (USEPA 2007).

Wildlife LC_{50}s (dietary) for animals with significant food sources in water

Toxicity tests on mallards are available in a report from the U.S. Fish and Wildlife Service that summarizes similar avian tests of 131 compounds. The dietary intake LC_{50} (lethal concentration for 50% of organisms tested) was reported to be 5000 ppm for mallards (Hill *et al.* 1982). The US EPA Environmental Risk Assessment for the Reregistration of Diuron (USEPA 2003a) states that diuron is practically nontoxic to mallard duck on an acute oral basis and slightly toxic to mallard duck on a subacute dietary basis.

Wildlife dietary NOECs for animals with significant food sources in water

No NOEC (no observed effect concentration) data was available for wildlife species with significant food sources in water.

5. Ecotoxicity data

Approximately 84 original studies of the effects of diuron on aquatic life were identified. Single-species effects studies that were rated as relevant (R) or less relevant (L) were summarized in data summary sheets (see section 3-2.2, TenBrook *et al.* 2009a). Copies of completed data summaries for all studies rated reliable and relevant (RR) for criteria derivation are included in the Appendix of this report. Information in these summaries was used to evaluate each study for reliability using the rating systems described in the methodology (section 3-2.2 of TenBrook *et al.* 2009a). Diuron studies deemed irrelevant from an initial screening were not summarized (e.g. studies involving *in vitro* exposures). Ecosystem-level studies were not summarized into the form mentioned above due to their complexity, but are reviewed in section 14. All data rated as acceptable or supplemental for criteria derivation are summarized in Tables 4 - 11 found at the end of this report.

Evaluation of aquatic animal data

Using the data evaluation criteria (section 3-2.2, TenBrook *et al.* 2009a), two acute studies yielding three toxicity values from two taxa were judged reliable and relevant for acute criterion derivation (Table 4). Three studies yielding ten animal toxicity values were rated RR for the chronic criteria (Table 7b). Twenty-four acute toxicity animal values from nine studies were rated RL, LL, or LR and were used as supplemental information for evaluation of the derived acute criteria (Table 6). Eight chronic toxicity animal values from five studies were rated RL, LL, or LR (Table 9b).

Evaluation of aquatic plant data

Plant data were used to derive the chronic criterion instead of chronic animal data because diuron is an herbicide and plants are the most sensitive taxa (section 3-4.3, TenBrook *et al.* 2009a). All plant studies were considered chronic because the typical endpoints of growth or reproduction are inherently chronic. Plant studies are much more

difficult to interpret than animal data because a variety of endpoints may be used, but the significance of each one is not clear. In this methodology, only endpoints of growth or reproduction (measured by biomass) and tests lasting at least 24-h had the potential to be rated highly and used for criteria calculation, which is in accordance with standard methods (USEPA 1996; ASTM 2007a, 2007b). According to these methods the test parameters of dissolved oxygen, hardness, alkalinity, and conductivity were not considered in the evaluation of reliability (full points were given for these parameters when plant studies were evaluated with Tables 3.7 and 3.8 in TenBrook *et al.* 2009a), as these are not relevant for plant studies. Otherwise, the plant studies were rated for quality using the data evaluation criteria (section 3-2.2, TenBrook *et al.* 2009a).

There are several endpoints listed in the tables for plant data. The endpoints are explained here for clarity and the description includes if the endpoint is clearly linked to survival, growth, or reproduction.

Growth inhibition: All of these endpoints are relative to a control growth measurement. Depending on the plant it may have been measured by direct cell counts with a hemacytometer, cell counts with a spectrophotometer, cell counts with an electronic particle counter, chlorophyll concentration measured by absorbance, turbidity measured by absorbance, root biomass, or number of fronds (*Lemna spp.*). In all cases, growth of exposed samples was compared statistically to controls.

Relative Growth Rate: Biomass of macrophytes was measured before and after exposure to calculate a growth rate as (final mass-initial mass)/initial mass x 100. This endpoint is very similar to growth inhibition, except it is expressed as a positive effect, while growth inhibition is expressed a negative effect.

Change in chlorophyll fluorescence ratio: Chlorophyll fluorescence was measured at a maximal fluorescence and either a variable or steady-state fluorescence and a ratio was computed. An increase in the ratio indicates a disruption of photosystem II, which may lead to a decrease in carbohydrate production and thus decreased growth. This ratio is a valid measurement that is related to algal growth according to ASTM Standard Method E1218-04 (ASTM 2004), but is described as less definitive than measuring chlorophyll *a* content.

Reduced oxygen evolution: Plants evolve oxygen during photosynthesis, and reduced photosynthesis has been shown to correlate well with the concentrations that inhibit growth by Walsh (1972), but it is not clear that this endpoint is a good predictor of growth inhibition across all plant species. This endpoint is always calculated as relative to controls.

Four studies yielding four plant toxicity values were rated RR for the chronic criterion derivation (Table 7a). Supplemental information for the derived chronic criteria includes 67 plant toxicity values from 18 studies (Table 9a).

One relevant study of terrestrial wildlife was found that studied the effects of diuron on ducks (Hill *et al.* 1982), which is discussed above in section 4.

6. Data reduction

Multiple toxicity values for diuron for the same species were reduced down to one species mean acute value according to procedures described in the methodology (section 3-

2.4, TenBrook *et al.* 2009a). Acceptable acute and chronic data that were excluded, and the reasons for their exclusion, are shown in Tables 5 and 8, respectively. The final acute animal, chronic plant, and chronic animal data sets are shown in Tables 4, 7a, and 7b, respectively.

7. Acute criterion calculation

An acute criterion was calculated with acute animal toxicity data only. This value is not intended to be protective of plants, as the chronic value is (see section 8). Since acceptable acute toxicity values were not available from the five required taxa, the acute criterion was calculated using the Assessment Factor procedure (AF, section 3-3.3, TenBrook *et al.* 2009a). This section of the methodology points out that these factors are limited in that they are based on organochlorine and one organophosphate pesticides, which are neurotoxic insecticides, while diuron is an herbicide that inhibits photosynthesis. However, diuron is a chlorinated compound that does exhibit toxicity to animals and the mechanism is not clear. Assessment factors in the methodology (TenBrook *et al.* 2009a) are the most specific assessment factors available for organic pesticides and will therefore be used with caution for diuron. Assessment factors from the Great Lakes Initiative (USEPA 2003b) could be another alternative, but they include a much wider variety of chemicals such as metals and industrial chemicals.

The two available taxa are shown in Table 4; missing from the taxa requirements are a fish from the family Salmonidae, a warm water fish, and an insect. The AF method calculates the criterion by dividing the lowest species mean acute value from the data set by a factor, which is determined by the number of data available. The lowest species mean acute value was the 48-h *Daphnia magna* LC_{50} value, which was 12 mg/L. This value was divided by an assessment factor of 36 because there are acceptable data from two taxa (Table 3.13, TenBrook *et al.* 2009a). The acute criterion calculated using the AF represents an estimate of the median 5^{th} percentile value of the species sensitivity distribution. To calculate the acute criterion from the recommended acute value a safety factor of 2 is applied (section 3-3.3, TenBrook *et al.* 2009a).

Acute value = 12 mg/L ÷ 36 = 0.3333 mg/L

Preliminary acute criterion = acute value ÷ 2 = 0.1667 mg/L = 168 µg/L

The lowest acute value in the data sets rated RR, RL, LR, or LL (Table 6) is 160 µg/L for the scud *Gammarus lacustris* (Sanders 1969). This study rated LL because the control response was not reported and many other study details were also not reported. The lack of information makes this study less reliable, but there were no obvious problems with the data (such as the study was conducted in saltwater or the endpoint could not be related to survival, growth, or reproduction). Additionally, there were no other data for this species or other amphipods to suggest this value is in error. With the considerations that very few data were available for the acute criterion calculation, that the AF may be of limited use for herbicides, and in order to be protective of all species in the supplemental data set, an additional safety factor of 2 was applied to the acute value.

168 µg/L ÷ 2 = 84 µg/L

Recommended acute criterion = 84 µg/L

The inclusion of this additional safety factor is essentially the same as taking the lowest value and diving it by 2 to derive an acute no-effect concentration from an LC_{50} (section 2-3.1.2, TenBrook *et al.* 2009a), which is how EPA derived an acute animal benchmark of 80 µg/L for diuron.

8. Chronic criterion calculation

The methodology for derivation of the chronic criterion of an herbicide (section 3-4.3, TenBrook *et al.* 2009a) was followed because diuron is an herbicide and the chronic data in Table 7a show that plants are the most sensitive taxa. Acceptable chronic toxicity values were not available for five families of plants or alga, so a distribution could not be fit to the available toxicity data. The methodology requires that in the absence of acceptable data to fit a distribution, the lowest NOEC value from an important alga or vascular aquatic plant species be used. Acceptable toxicity data for the green algae *Pseudokirchneriella subcapitata* (formerly *Selenastrum capricornutum)* is shown in Table 7a, and the NOEC value reported there serves as the chronic criterion.

Chronic criterion = 1.3 µg/L

9. Bioavailability

Few studies were found concerning the bioavailability of diuron, and only one study was found pertaining to bioavailability to organisms in the water column. Knauer *et al.* (2007) found that the presence of black carbon (BC) in the water column can reduce the toxicity of diuron to the freshwater green algae *Pseudokirchneriella subcapitata* (formerly *Selenastrum capricornutum)* due to sorption of diuron to BC. Black carbon is ubiquitous in the environment because it is a product of incomplete combustion and can act as a supersorbent for some organic contaminants, but it is only a small fraction of total organic carbon, which is usually responsible for the majority of sorption to solids. BC in its native form compared to isolated and re-combusted BC was much less effective at sorbing diuron, and therefore reducing toxicity. This study indicates that sorption of diuron to BC reduces bioavailability, but it does not provide enough information about sorption to recommend basing compliance on less than the whole water concentrations. No other information about bioavailability of diuron in the water column that differentiates when diuron is sorbed to solids, sorbed to dissolved solids, or freely dissolved was found. Until there is more information that discusses the bioavailability of these three phases, compliance must be based on the total concentration of diuron in water.

10. Mixtures

Diuron can occur in the environment with other herbicides of similar or different modes of action. Diuron is a photosystem II (PSII) inhibitor as are all phenylurea herbicides. Other widely used herbicides, such as the triazines, are also PSII inhibitors, but have different binding sites than the phenylurea herbicides. The concentration addition model and the non-additive interaction model are the only predictive mixture models recommended by the methodology (section 3-5.2, TenBrook *et al.* 2009a), so other models found in the literature will not be considered for compliance.

Several studies have confirmed that toxicity of a mixture of herbicides that are PSII inhibitors can be predicted by the concentration addition method (Arrhenius *et al.* 2004; Backhaus *et al.* 2004; Knauert *et al.* 2008). Knauert *et al.* (2008) studied the effects of a mixture of the herbicides diuron, atrazine and isoproturon, as well as the single herbicides, in a mesocosm environment using the toxicity unit (TU) approach. In these tests, single herbicides exhibited the same inhibition of phytoplankton photosynthesis as a mixture containing 1/3 the toxicity unit concentration of each herbicide, showing that the TU approach is an accurate for calculating toxicity of a mixture of PSII-inhibitor herbicides. Backhaus *et al.* (2004) tested a mixture of 12 phenylurea herbicides with a unicellular green alga *Scenedesmus vacuolatus* and found that the combined toxicity could be predicted by concentration addition, but also equally well by independent action. Arrhenius *et al.* (2004) also concluded that the concentration addition method is accurate for predicting mixture toxicity for PSII-inhibitor herbicide mixtures in algal communities. Based on this evidence, the concentration addition method should be used to determine compliance in cases where PSII inhibitor mixtures occur if the other pesticides considered in the model have numeric water quality criteria. If numeric water quality criteria are not available for the other pesticides the model cannot be used and diuron should be considered alone.

Lydy and Austin (2005) studied the toxicity mixtures of diuron with organophosphate insecticides to *Chironomus tentans* and found some acted as synergists with diuron. The synergistic ratios (K) for diuron in a binary mixture with 50 μg/L chlorpyrifos or 100 μg/L methidathion are 1.5 and 4.8, respectively. Diuron mixed with azinphos methyl or diazinon produced no effect on toxicity. However, because the K value is only for a single species at a single concentration it cannot be used to assess compliance with water quality criteria; it can be used to assess the potential harm for *Chironomus tentans* itself if there are numeric water quality criterion for chlorpyrifos and methidathion.

Teisseire *et al.* (1999) examined the phytotoxicity of diuron combined with two fungicides (copper and folpet) on duckweed (*Lemna minor*) because these pesticides are often used in combination in vineyards. They found that growth inhibition due to the combination of diuron and copper depended on the concentrations of both chemicals, while it only depended on the diuron concentration when combined with folpet. The combination of copper and diuron was found to be additive for most concentrations, but slight antagonism was observed for several concentrations. This data cannot be used to determine compliance because neither the concentration addition nor the non-additivity model can be used. The concentration addition model cannot be used because diuron and copper do not have the same modes of action and a multi-species K value is not available for this mixture so the non-additivity model cannot be used.

Diuron is widely used as an anti-fouling biocide in paint for ship hulls and can be used in combination with other anti-fouling agents. Several articles were found that studied the toxicity of mixtures of diuron and other anti-fouling agents, including: Irgarol (cybutryne) and Sea nine 211 (4, 5-dichloro-2-n-octyl-3(2H)-isothiazolone) (Fernandez-Alba *et al.* 2002); diuron metabolites and copper (Gatidou and Thomaidis 2007); chlorothalonil, copper pyrithione, and zinc pyrithione (Koutsaftis and Aoyama 2007); copper and Irgarol (Manzo *et al.* 2008); Irgarol (Chesworth *et al.* 2004); and tri-*n*-butyltin (Molander *et al.* 1992b). Resulting toxicities were synergistic, additive, and antagonistic for different mixtures, sometimes depending on concentration ratios and how many compounds were in the mixture. None of these studies reported a coefficient of interaction and most were saltwater so the data cannot be used to assess mixture toxicity, but they do provide evidence that synergistic, additive and antagonistic effects are all possible with other chemicals commonly used with diuron.

Other studies have focused on mixtures with contaminants or other types of pesticides. Walker (1965) found that diuron combined with trichloroacetate (TCA), used for aquatic plant control in aquaculture, reduced the bluegill EC_{50} 4-5 fold compared to diuron alone. The author also states that the carrier in the emulsifiable mixture of diuron and TCA contributed to the increased toxicity. Hernando *et al.* (2003) found that methyl-*tert*-butyl ether (MTBE), a common ground and surface water contaminant, had a synergistic effect when used in combination with diuron. The addition of MTBE increased diuron toxicity to the bacterium *Vibrio fischeri* by 50% in a shorter exposure duration than diuron alone. *Daphnia magna* was also tested with the combination, but no change in toxicity was observed compared to diuron alone. A coefficient of interaction was not calculated so this data cannot be used to assess criteria compliance.

In summary, when diuron is detected with other photosystem II (PSII) inhibitor herbicides the toxicity should be predicted by the additive concentration addition model. There are no multi-species coefficients of interaction reported in the literature, so the non-additive interaction model cannot be used to assess water quality criteria compliance.

11. Temperature, pH, and other water quality effects

There were no studies available that examined the effects of temperature or pH on toxicity in the aqueous environment. As diuron is only a very weak base, pH is not expected to have a significant affect on the chemical structure.

12. Sensitive species

The derived acute criterion (84 µg/L) is protective of the lowest acute value in the data set. The lowest acute value in the data sets rated RR, RL, LR, or LL is 160 µg/L for the scud *Gammarus lacustris* (Sanders 1969). Section 7 describes how an additional safety factor of 2 was applied to the initial acute criterion of 168 µg/L, which is very close to the scud LC_{50} value. Based on the available data, the additional safety factor should provide protection for sensitive aquatic invertebrates.

The derived chronic criterion (1.3 μg/L) is below all chronic data that was highly rated, while there are some values that are lower in the supplemental data set rated RL or LL. The chronic criterion was not adjusted because the lower values did not meet the relevance and reliability standards defined by Tables 3.6-3.8 in the methodology (TenBrook *et al.* 2009a). More specifically, each of the studies with toxicity values lower than the derived chronic criterion either do not provide enough information to show that the tests were completed in a reliable manner, or they do not use endpoints or exposure durations that are known to be relevant to organism survival, growth or reproduction. These studies are discussed in detail below.

The lowest measured chronic value in the data sets is an EC_{50} of 0.00026 μg/L for the rooted macrophyte *Apium nodiflorum* for a nonstandard endpoint of root growth (Lambert *et al.* 2006). This value was calculated by extrapolation and is lower than the reported NOEC and below the lowest concentration tested, and therefore is not a toxicity value that should be used for criteria calculation. Several other toxicity values from this study are below the derived chronic criterion, but a standard method was not used, no control responses were reported and the study rated low (L) for reliability, so use of these values is not recommended. Podola and Melkonian (2005) report NOEC and LOEC values below the derived chronic criterion for nine different algae, but this study used a non-standard endpoint and duration that does not provide a clear link to an adverse effect on succession of the organisms. Two studies that used saltwater organisms (Ukeles 1962; Walsh & Grow 1971) report toxicity values below the derived chronic criterion, but saltwater organisms are suspected to have different sensitivities than freshwater organisms; therefore, they are not used to derive freshwater criteria. The values in Table 9a indicate that saltwater organisms may be generally more sensitive to herbicides than freshwater organisms. Two studies (Ma *et al.* 2001; Ma 2002) containing the same data for the alga *Chlorella pyrenoidosa* reported EC_{50} values equal to the derived criterion. These studies used diuron with purity of less than 80%, did not report a control response and were rated L for reliability because many other standard study details were not reported. Another study by Ma *et al.* (2006) reported an EC_{50} below the derived criterion, but also used diuron of low purity and lacked other study details. It is very important to use chemicals of high purity in toxicity testing because impurities or other chemicals present in formulations may cause toxicity effects unrelated to the chemical of interest. Eullaffroy and Vernet (2003) report a toxicity threshold of 1 μg/L for green algae with an exposure time of only 1 min. This study did not follow a standard method or exposure time and it is not clear that the endpoint measured is significant for the organism. Overall, it is recommended that the chronic plant toxicity values in the supplemental data that are below the derived chronic criterion not be used to adjust the criterion, because the studies were not found to be relevant and reliable for criteria generation.

13. Bioaccumulation

Bioconcentration of diuron has been measured in fathead minnow, mosquito fish, snails, daphnids, and algae. Diuron has a log K_{ow} of 2.78 (Sangster Research Laboratories 2008), and a molecular weight of 233.1, which indicates a low bioaccumulative potential.

There is an EPA pesticide tolerance for farm-raised freshwater finfish tissue of 2.0 mg/kg (USEPA 2007), but there are no FDA food tolerances for diuron (USFDA 2000).

Isensee (1976) measured bioconcentration in model ecosystems of mosquito fish (*Gambusia affinis)*, snails *(Physa spp*.), daphnids (*Daphnia magna),* and algae (*Oedogonium cardiacum).* The model ecosystem was designed to simulate contamination due to erosion. Soil was spiked with ^{14}C-labeled diuron and clean water was added and allowed to equilibrate 1 d before all organisms were added, except fish, which were added after 30 d, when daphnids were removed and analyzed. All other animals were harvested and analyzed at 33 d. Bioconcentration factors (log BCF) for the four organisms range from 1.60-2.46 and are listed above in Table 1 of section 3.

Bioconcentration of diuron was measured in fathead minnow by Call *et al.* (1987). Test aquaria water was spiked with ^{14}C-labeled diuron containing 30 d old fathead minnows at two aqueous concentrations (3.15 and 30.4 µg/L). Fish were removed and analyzed at nine time points up to 24 d. A mean bioconcentration factor (log BCF) of 2.0 was determined for diuron from the two test concentrations.

There is little evidence to show that diuron is a bioaccumulation threat in the environment. There is also documentation of rapid metabolism and elimination of diuron in fathead minnows and rainbow trout (Call *et al.* 1987).

To check that these criteria are protective of terrestrial wildlife that may consume aquatic organisms, a bioaccumulation factor (BAF) is used to estimate the water concentration that would roughly equate to a reported toxicity value for such terrestrial wildlife ($LC_{50,\ oral\ predator}$). The BAF of a given chemical is the product of the bioconcentration factor (BCF) and a biomagnification factor (BMF), such that BAF=BCF*BMF. The dietary LC_{50} of 5000 mg/kg for mallard and a BCF value of $10^{2.46}$ L/kg for *Gambusia affinis* given by Isensee (1976) were used as an example estimation of bioaccumulation in the environment. A default BMF of 1 was chosen based on the log K_{ow} (Table 3.15, TenBrook *et al.* 2009a) because no biomagnification data was found in the literature.

$$NOEC_{water} = \frac{LC_{50,oral\_predator}}{BCF_{food\_item} * BMF_{food\_item}}$$

Mallard:
$$NOEC_{water} = \frac{5000\ ^{mg}/_{kg}}{10^{2.46}\ ^{L}/_{kg} * 1} = 173\ ^{mg}/_{L} = 173{,}000\ ^{\mu g}/_{L}$$

The EPA pesticide tolerance for farm-raised freshwater finfish tissue of 2.0 mg/kg (USEPA 2007) was used to make a similar estimation for human health. This is an attempt to anticipate if concentrations allowed by the derived chronic criterion could bioaccumulate in fish to a level that could be toxic to a human that consumes the fish.

Human: $$NOEC_{water} = \frac{2.0\ ^{mg}/_{kg}}{10^{2.46\ ^{L}/_{kg}} * 1} = 0.0070\ ^{mg}/_{L} = 7.0\ ^{\mu g}/_{L}$$

In this example, the calculated chronic criterion is 13,300- fold below the estimated $NOEC_{water}$ value for wildlife and is not expected to cause adverse effects due to bioaccumulation. However, the chronic criterion is only 5-fold below the estimated $NOEC_{water}$ value for human health, and this may be an area that needs additional review to ensure there is no conflict between these criteria and human health standards.

14. Ecosystem and other studies

Eleven mesocosm, microcosm or ecosystem (field and laboratory) studies were identified. Two studies were done on saltwater species and can only be used as supplemental information (Molander & Blanck 1992a; Devilla *et al.* 2005). Nine of the freshwater studies rated as acceptable (R or L; Table 10). Three of the studies were rated R (Hartgers *et al.* 1998; Sumpono *et al.* 2003; Tlili *et al.* 2008), and six were rated L (Flum & Shannon 1987; Molander & Blanck 1992a; Zimba *et al.* 2002; Perschbacher & Ludwig 2004; Pesce *et al.* 2006; Dorigo *et al.* 2007) and are used as supporting data. These studies were almost all indoor or laboratory studies mimicking small river or pond natural environments and examining microbial, phytoplanktonic, or bacterial communities. Most of these studies noted an initial drop in phytoplankton biomass, which led to a decrease in dissolved oxygen due to the decay of the phytoplankton. Two studies report a community EC_{50} value (concentration producing an effect in 50% of tested organisms; Flum & Shannon 1987; Dorigo *et al.* 2007), and one study reported a NOEC (Hartgers *et al.* 1998) to which the calculated criteria may be compared.

Plankton communities have displayed varying degrees of response to diuron, depending on, among other things, the concentrations applied. Hartgers *et al.* (1998) set up microcosms containing phyto-, peri-, bacterio- and zooplankton and monitored them for a 28 d chronic exposure to a mixture of diuron, atrazine, and metolachlor, and a 28 d recovery period. A NOEC for the mixture based on phytoplankton was determined to be 1.5 µg/L diuron, 5.4 µg/L atrazine, and 5.6 µg/L metolachlor. The diuron value is slightly higher than the chronic criterion and therefore would be protective of phytoplankton based solely on diuron. Flum and Shannon (1987) reported an 96-hr EC_{50} of 2205 µg/L (1630-3075 µg/L 95% CI) for an artificial microecosystem containing zooplankton, amphipods, ostracods, unicellular and filamentous algae, protozoans, and microbes. The EC_{50} value was based on monitoring the redox potential, pH, and dissolved oxygen as measure of toxicity.

Plankton and algae communities exposed to diuron have been studied in regard to the aquaculture industry because some algae give fish an "off" flavor, but plankton are necessary for healthy ponds. Zimba *et al.* (2002) assessed the effect of 9 weeks of diuron application (10 µg/L) on catfish pond ecology. Algae, phyto-, zoo-, and ultraplankton composition and biomass were examined as well as water quality. The only significant effect of the diuron exposure was a change in the phytoplankton composition, but the phytoplankton biomass was not altered. Perschbacher and Ludwig (2004) also studied plankton communities in outdoor pool mesocosms simulating aquaculture ponds. Three

diuron concentrations were tested and monitored for 4 weeks post-application. Diuron depressed primary production and biomass of phytoplankton for at least 4 weeks post-application, which in turn caused a decrease in dissolved oxygen to levels that are potentially lethal to fish. The concentrations were reported as field rate (1.4 kg a.i./ha), 1/10 field rate, and 1/100 field rate of Direx without adjuvants, but were not measured. Low DO (< 4 ppm) occurred only for the two highest diuron applications at 10 d post-application and it took until three weeks post-application for DO levels to return to close to that of the control ponds. Fish were not used in this study, but it is known that low DO can be potentially lethal to fish.

Tlili *et al.* (2008) studied biofilm communities in a small river with chronic exposure to 1 μg/L diuron, as well as 3-hour pulses of 7 μg/L or 14 μg/L diuron with and without prior exposure. The results indicate that photosynthesis was never significantly inhibited by any of the treatments, but the pulses did alter the community structure of the microalgae. The pulses affected the eukaryotic community structure in microcosms that did not have prior chronic diuron exposure, but had no significant impact on those that did have prior exposure. Dorigo *et al.* (2007) assessed prokaryotic and eukaryotic communities and microalgae exposed to vineyard runoff water in a small stream containing diuron concentrations of 0.09 and 0.43 μg/L. The diuron tolerance in these communities increased in the downstream direction and the pristine control site had the lowest tolerance, following the concept that contaminant exposure increases the tolerance of biofilms either by adaptation or species changes. The endpoints in these studies are not clearly linked to survival, growth and reproduction and do not exhibit a clear dose-response relationship, so it is not clear if diuron exposure at these levels impacted the diversity of species of biofilm communities. Biofilm community restructuring may have long-term effects on an ecosystem, however, the studies available only provide preliminary data on this subject. If more in-depth data becomes available on this topic in the future it should be incorporated into criteria derivation.

Several other studies also look at the impact of diuron on microbes. Pesce *et al.* (2006) reported that a 21 d exposure of 10 μg/L prevented the implementation and development of a productive microbial community in a riverine microcosm, but the derived chronic criterion is well below this concentration. Sumpono *et al.* (2003) studied the effects of diuron on aquatic bacteria in a wastewater treatment pond model ecosystem. The single concentration exposure was 12.5 mg/L, which is well above the acute and chronic criteria. Photosynthetic microorganisms decreased, but bacteria proliferated with diuron exposure, likely due to the bacteria using the detritus as a new carbon source.

The literature shows that herbicides in aquatic ecosystems may have detrimental effects on the bottom of the food chain, which may indirectly impact species up the food chain via changes in water quality or decreased food supply. However, many of these studies only tested a single concentration so that no dose-response relationship can be inferred and no-effect concentrations are not available. From the studies cited it appears that the derived acute and chronic criteria could be protective of these types of negative effects because most studies used much higher exposure concentrations. The only studies that report effects at concentrations lower than the derived chronic criterion are for the non-

standard endpoint of biofilm community restructuring, which are preliminary data that cannot be incorporated into criteria derivation until more in-depth studies are available (Tlili *et al.* 2008, Dorigo *et al.* 2007). Based on the currently available ecosystem studies the derived acute and chronic criteria appear to be protective of aquatic organisms.

15. Threatened and endangered species

Current lists of state and federally listed threatened and endangered plant and animal species in California were obtained from the California Department of Fish and Game website (CDFG 2008). Several listed animal species are represented in the dataset. Five Evolutionarily Significant Units of *Oncorhynchus mykiss* are listed as federally threatened or endangered throughout California. The acute data set includes an LC_{50} value for *O. mykiss* of 1.95 mg/L from a 1976 EPA study that was rated NL because there was very little description of the study. Data is also available for Cutthroat trout (*Oncorhynchus clarki*), of which the subspecies Lahontan cutthroat trout (*O. c. henshawi)* is listed as federally threatened. The *O. clarki* data is from an EPA dataset compiled by Mayer and Ellersieck (1986) rated NL due to a lack of study description. There are ten Cutthroat trout LC_{50} values in this study that range from 1.4-13.8 mg/L depending on the study parameters, which varied pH, temperature, fish size and age. These data indicate that the acute criterion of 84 µg/L would be protective of these two species, although the data is not rated highly. The California red-legged frog (*Rana aurora draytonii*) is represented in the data set by *Rana aurora* from a study rated RR with an LC_{50} of 22.2 mg/L for a 14-d test, well above the derived criteria.

The USEPA interspecies correlation estimation (ICE v. 1.0; USEPA 2003b) software was used to estimate toxicity values for the listed animals or plants represented in the acute data set by members of the same family or genus. Table 11 summarizes the results of the ICE analyses. The values in Table 11 range from 0.753 mg/L for Lahontan cutthroat trout to 2.34 mg/L for Chinook salmon. The value of 1.029 mg/L estimated by ICE for *O. mykiss* is in reasonable agreement with the measured value of 1.95 mg/L.

No plant studies used in the criteria derivation were of state or federal endangered, threatened or rare species. Plants are particularly sensitive to diuron because it is an herbicide, but there are no aquatic plants listed as state or federal endangered, threatened or rare species so they could not be considered in this section.

Based on the available data and estimated values for animals, there is no evidence that the calculated acute and chronic criteria will be underprotective of threatened and endangered species.

16. Harmonization with air and sediment criteria

This section addresses how the maximum allowable concentration of diuron might impact life in other environmental compartments through partitioning. The only available sediment criterion for diuron is estimated based on partitioning from water using empirical K_{oc} values. There are no other federal or state sediment or air quality standards for diuron

(CDWR 1995; CARB 2008), nor is diuron mentioned in the NOAA sediment quality guidelines (NOAA 1999). For biota, the limited data on bioconcentration or biomagnification of diuron is addressed in section 13.

17. Limitations, assumptions, and uncertainties

The assumptions, limitations and uncertainties involved in criteria generation are available to inform environmental managers of the accuracy and confidence in the criteria. Chapter 2 of the methodology (TenBrook *et al.* 2009a) discusses these points for each section as different procedures were chosen, such as the list of assumptions associated with using an SSD, included in section 2-3.1.5.1, and reviews them in section 2-7. This section summarizes any data limitations that affected the procedure used to determine the final diuron criteria.

As diuron is an herbicide the most important limitation is the lack of plant data. The chronic dataset only contained four plant values, making it difficult to ensure protection of aquatic plants. Additionally plant and algal data is difficult to interpret. The assumptions that went into evaluation of these studies are described in section 5. Animal data were also lacking as only two of the five acute animal taxa requirements were met. Chronic animal taxa requirements were almost met, only data on a cold water fish was missing. Although diuron is an herbicide, some animals do show sensitivity to it. Confidence intervals or other measures of uncertainty could not be calculated for either criterion because they are each based on only one value.

18. Final criteria statement

The final criteria statement is:

Aquatic life in the Sacramento River and San Joaquin River basins should not be affected unacceptably if the four-day average concentration of diuron does not exceed 1.3 µg/L (1300 ng/L) more than once every three years on the average and if the one-hour average concentration does not exceed 84 µg/L more than once every three years on the average.

The US EPA has several aquatic life benchmarks established for diuron to which the derived criteria in this report can be compared, shown in Table 3 (USEPA 2003a).

Table 3. US EPA Aquatic Life Benchmarks (USEPA 2003a). All units are µg/L.

Acute Fish	Chronic Fish	Acute Invertebrates	Chronic Invertebrates	Acute nonvascular plants
355	26	80	160	2.4

The derived acute criterion of this report is below the acute fish benchmark of the EPA, and only slightly above the acute invertebrate benchmark. The derived chronic criterion of this report is below the chronic benchmarks for fish and invertebrates, as well as the acute

nonvascular plant benchmark. Because the chronic criterion was derived using only plant data, it is most comparable to the acute nonvascular plant benchmark. The Environmental Risk Assessment for the Reregistration of Diuron (USEPA 2003a) cites the same green algae study used in this report as the only acceptable plant data for diuron, but the authors use the EC_{50} value of 2.4 µg/L as a benchmark, instead of the NOEC value of 1.3 µg/L. The use of the EC_{50} value is required according to the EPA methodology for calculation of an acute benchmark (USEPA 2003a). The use of the NOEC value as the chronic criterion is recommended in order to be protective of nonvascular plants.

The acute criterion is based only on acute animal data. Details of the acute criterion calculation are described in section 7 and the data used are shown in Table 4. An assessment factor was used instead of a distribution to calculate the acute criterion because there were not sufficient data from the five required taxa. An additional safety factor of 2 was applied to the acute value in order to be protective based on data in the supplemental data set.

Details of the chronic criterion calculation are described in section 8 and the dataset is shown in Table 7a. The lowest NOEC of a highly rated plant study was used as the criterion because there were insufficient data for a distribution of toxicity data. Some plant toxicity values in the supplemental data sets and in mesocosm studies are lower than the derived chronic criterion, but based on the lack of reliability or relevance of these studies, discussed in section 12 and 14, it is not currently recommended that the criteria be adjusted. Toxicity to plants is essential when considering regulations and diuron usage because plants and algae are the most sensitive taxa, however, plant data are difficult to interpret. These criteria were derived using the best data found, and firm evidence that could support lowering criteria was not found. The criteria should be updated whenever new relevant and reliable data is available.

One final note concerns the averaging periods of the acute and chronic criteria. The chronic 4 h averaging period should be protective based on available data. However, the acute criterion is very high when compared to plant data, and it may allow for a pulse that could kill off a large amount of algae, resulting in increased biological demand (BOD) and potential fish kills due to low DO (see section 14). Necessary information on the timing and concentrations that could cause this effect is not obvious from the data found.

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Data Tables

Table 4. Final acute toxicity data set for diuron. All studies were rated RR and were conducted at standard temperature. S: static; SR: static renewal; FT: flow-through.

Species	Common Identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	LC/EC_{50} (µg/L) (95% CI)	Reference
Daphnia magna	Daphnid	Daphniidae	S	Nom	80.0%	48-h	19.9	Mortality/ Immobility	< 24-h	12000 (10000-13000)*	Baer 1991
Daphnia pulex	Daphnid	Daphniidae	SR	Meas	99.8%	96-h	22	Mortality	5-d	17900 (14200-22600)	Nebeker & Schuytema 1998
Hyalella azteca	Amphipod	Hyalellidae	SR	Meas	99.8%	96-h	22	Mortality	<11 d	19400 (17700-21300)	Nebeker & Schuytema 1998

* Lowest value used for criteria calculation because not enough data available for a distribution

Table 5. Acceptable reduced acute data rated RR with given reason for exclusion. S: static; SR: static renewal; FT: flow-through.

Species	Common Identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC_{50} (µg/L) (95% CI)	Reference	Reason
Daphnia magna	Daphnid	Daphniidae	S	Nom	80.0%	24-h	19.9	Mortality/ Immobility	< 24-h	68000 (55000-86000)	Baer 1991	A

Reduction Reasons

A. Not the most sensitive or appropriate duration

Table 6. Excluded acute data rated RL, LR, LL with given reason for rating and exclusion. S: static; SR: static renewal; FT: flow-through. NR: not reported. 95% CI: 95% confidence interval. Exclusion reasons are listed at the end of the table.

Species	Common Identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	LC/EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason
Artemia salina	Brine Shrimp	Artemiidae	S	NR	NR	24-h	25	Mortality	Instar II-III larvae	12010 (11420-12100)	Koutsaftis & Aoyama 2007	LL 2, 5
Asellus brevicaudus	Aquatic sow bug	Asellidae	S	Nom	95.0%	96-h	15	Mortality	Mature	15500 (7200-33400)	Johnson & Finley 1980	LL 5, 6
Ctenopharyngodon idella	Grass carp	Cyprinidae	FT	NR	100.0%	96-h	13	Mortality	1+ year, 15.8 g, 9.5 cm	31000 (28000-34000)	Tooby et al. 1980	LL 1, 5, 6
Daphnia magna	Daphnid	Daphniidae	S	Nom	Technical grade	26-h	21.1	Mortality/ Immobility	1st instar	47000 (41600-53100)	Crosby & Tucker 1966	LL 1, 5, 6
Daphnia pulex	Daphnid	Daphniidae	S	Nom	95.0%	48-h	15	Mortality/ Immobility	1st instar	1400 (1000-1900)	Johnson & Finley 1980	LL 5, 6
Gammarus fasciatus	Scud (amphipod crustacean)	Gammaridae	S	Nom	Technical grade	24-h	15.5	Mortality	early instar	2500 (1000-5500)	Sanders 1970	LL 1, 5, 6
Gammarus fasciatus	Scud (amphipod crustacean)	Gammaridae	S	Nom	Technical grade	48-h	15.5	Mortality	early instar	1800 (800-5200)	Sanders 1970	LL 1, 5, 6
Gammarus fasciatus	Scud (amphipod crustacean)	Gammaridae	S	Nom	Technical grade	96-h	15.5	Mortality	early instar	700 (190-8200)	Sanders 1970	LL 1, 5, 6
Gammarus lacustris	Scud (amphipod crustacean)	Gammaridae	S	Nom	Technical grade	24-h	21.1	Mortality	2 months old	700 (590-8300)	Sanders 1969	LL 1, 5, 6
Gammarus lacustris	Scud (amphipod crustacean)	Gammaridae	S	Nom	Technical grade	48-h	21.1	Mortality	2 months old	380 (290-500)	Sanders 1969	LL 1, 5, 6
Gammarus lacustris	Scud (amphipod crustacean)	Gammaridae	S	Nom	Technical grade	96-h	21.1	Mortality	2 months old	160 (130-190)	Sanders 1969	LL 1, 5, 6

Species	Common Identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/ size	LC/EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason
Lepomis macrochirus	Bluegill Sunfish	Centrarchidae	S	Nom	Technical grade	96-h	12.7	Mortality	0.6-1.5 g	8900 (8200-9600)	Macek et al. 1969	LL 1, 5, 6
Lepomis macrochirus	Bluegill Sunfish	Centrarchidae	S	Nom	Technical grade	96-h	18.3	Mortality	0.6-1.5 g	7600 (7000-8200)	Macek et al. 1969	LL 1, 5, 6
Lepomis macrochirus	Bluegill Sunfish	Centrarchidae	S	Nom	Technical grade	96-h	23.8	Mortality	0.6-1.5 g	5900 (5300-6500)	Macek et al. 1969	LL 1, 5, 6
Lymnaea spp.	Snail	Lymnaeidae	S	Nom	NR	96-h	NR	Mortality	Adult	15300	Christian & Tate 1983	LL 1, 3, 6
Oncorhynchus clarki (Salmo clarki)	Cutthroat Trout	Salmonidae	S	Nom	95.0%	96-h	10.0	Mortality	3.00 g	1400 (1100 - 1900)	Johnson & Finley 1980	LL 5, 6
Oncorhynchus mykiss (Salmo gairdneri)	Rainbow Trout	Salmonidae	S	Nom	95.0%	96-h	13	Mortality	0.8 g	4900 (4100-5900)	Johnson & Finley 1980	LL 5, 6
Oncorhynchus mykiss (Salmo gairdneri)	Rainbow Trout	Salmonidae	S	Nom	80.0%	96-h	13	Mortality	1.2 g	16000 (11300-22700)	Johnson & Finley 1980	LL 5, 6
Pteronarcys californica	Stonefly Naiad	Pteronarcidae	S	Nom	95.0%	96-h	15	Mortality	2nd year class	1200 (900-1700)	Johnson & Finley 1980	LL 5, 6
Pteronarcys californica	Stonefly Naiad	Pteronarcidae	S	Nom	Technical grade	24-h	15.5	Mortality	30-35 mm	3600 (2800-4700)	Sanders & Cope 1968	LL 1, 5, 6
Pteronarcys californica	Stonefly Naiad	Pteronarcidae	S	Nom	Technical grade	48-h	15.5	Mortality	30-35 mm	2800 (2100-3800)	Sanders & Cope 1968	LL 1, 5, 6
Pteronarcys californica	Stonefly Naiad	Pteronarcidae	S	Nom	Technical grade	96-h	15.5	Mortality	30-35 mm	1200 (870-1700)	Sanders & Cope 1968	LL 1, 5, 6
Salvelinus namaycush	Lake Trout	Salmonidae	S	Nom	95.0%	96-h	10	Mortality	1.5 g	2700 (2400-3000)	Johnson & Finley 1980	LL 5, 6
Simocephalus serrulatus	Water fleas, daphnid	Daphniidae	S	Nom	95.0%	48-h	15	Mortality	1st instar	2000 (1400-2800)	Johnson & Finley 1980	LL 5, 6

Exclusion Reasons

1. Not a standard method
2. Saltwater
3. Low chemical purity or purity not reported
4. Toxicity value not calculable
5. Control response not reported
6. Low reliability score

Table 7a. Final chronic plant toxicity data set for diuron. All studies were rated RR. S: static; SR: static renewal; FT: flow-through. NR: not reported, n/a: not applicable

Species	Common identifier, Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	EC_{50} (µg/L)	Reference
Chlamydomonas moewusii Gerloff	Algae, Chlamydomonadaceae	S	Nom	80.0%	7-d	21	Growth inhibition	7-d old algal cell stock	NR	NR	NR	559.44	Cain & Cain 1983
Lemna minor	Duckweed, Araceae	S	Nom	98.0%	7-d	25	Growth inhibition	Plant fronds	NR	5	NR	25	Teisseire et al. 1999
Pseudokirchneriella subcapitata (Selenastrum capricornutum Printz)	Green algae	S	Nom	96.8%	120 h	24	Growth inhibition	2-d old algal cells	1.3	2.5	1.8	2.9	Blasburg et al. 1991
Scenedesmus obliquus	Microalgae, Scenedesmaceae	S	Nom	Technical	24 h	21	Growth inhibition	Algal cells	NR	NR	NR	10	Geoffroy et al. 2002

Table 7b. Final chronic animal toxicity data set for diuron. All studies were rated RR. S: static; SR: static renewal; FT: flow-through. NR: not reported

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference
Chironomus tentans	Midge	SR	Meas	99.8%	10-d	24	Mortality	2-d, 1st instar larvae	1900	3400	2540	Nebeker & Schuytema 1998
Daphnia pulex	Daphnid	S	Meas	99.8%	7-d	NR	Reduced # of young/ mortality	5-d old	4000.0	7700	5550	Nebeker & Schuytema 1998
Hyalella azteca	Amphipod	SR	Meas	99.8%	10-d	22	Mortality/ Reduced weight	< 11-d	7900	15700	11140	Nebeker & Schuytema 1998
Lumbriculus variegatus	Annelid worm	SR	Meas	99.8%	10-d	23	Reduced weight	small, short adults	1800	3500	2510	Nebeker & Schuytema 1998
Physa gyrina	Snail	SR	Meas	99.8%	10-d	24	Reduced weight	2-d 1st instar larvae	13400	22800	17480	Nebeker & Schuytema 1998
Pimephales promelas	Fathead minnow	FT	Meas	98.6%	64-d	25	Deformity, Mortality	Eggs < 24-h, hatched fry	33.4	78	51	Call et al. 1983, 1987
Pseudacris regilla	Pacific treefrog	SR	Meas	99.8%	14-d	20	Growth inhibition (Length)	Tadpole	14500	21100	17490	Schuytema & Nebeker 1998
Rana aurora	Red-legged frog	SR	Meas	99.8%	7-d	20	Growth inhibition (Wet weight)	Tadpole	7600	14500	10500	Schuytema & Nebeker 1998
Rana catesbeiana	Bullfrog	SR	Meas	99.8%	21-d	24	Growth inhibition (Dry weight)	Tadpole	11690*	16430*	12450*	Schuytema & Nebeker 1998
Xenopus laevis	African clawed frog	SR	Meas	99.8%	4-d	24	Growth inhibition (Length)	Embryo	10490**	20540**	14680**	Schuytema & Nebeker 1998

*SMCV calculated from 3 values

** SMCV calculated from 2 values

Table 8. Acceptable reduced chronic data rated RR with reason for exclusion given below. S: static; SR: static renewal; FT: flow-through. NR: not reported

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference	Reason for exclusion
Chironomus tentans	Midge	SR	Meas	99.8%	10-d	24	Reduced weight	2-d, 1st instar larvae	3400	7100	4910	Nebeker & Schuytema 1998	A
Pimephales promelas	Fathead minnow	SR	Meas	99.8%	7-d	25	Reduced weight	2.5 d embryo	4200	8300	5900	Nebeker & Schuytema 1998	C
Pimephales promelas	Fathead minnow	SR	Meas	99.8%	10-d	24	Mortality	1.5 month old juvenile	20000	27100	23280	Nebeker & Schuytema 1998	B
Pseudacris regilla	Pacific treefrog	SR	Meas	99.8%	10-d	20	Increased Deformity	Embryo	14500	29100	20540	Schuytema & Nebeker 1998	A
Pseudacris regilla	Pacific treefrog	SR	Meas	99.8%	14-d	20	Growth inhibition (Wet weight)	Tadpole	21000	29100	24720	Schuytema & Nebeker 1998	A
Pseudacris regilla	Pacific treefrog	SR	Meas	99.8%	14-d	20	Growth inhibition (Dry weight)	Tadpole	21100**	29100**	24750**	Schuytema & Nebeker 1998	A
Rana catesbeiana	Bullfrog	SR	Meas	99.8%	21-d	24	Growth inhibition (length)	Tadpole	14500**	24780**	18950**	Schuytema & Nebeker 1998	A
Rana catesbeiana	Bullfrog	SR	Meas	99.8%	21-d	24	Growth inhibition (Wet weight)	Tadpole	17490**	29100**	22560**	Schuytema & Nebeker 1998	A
Xenopus laevis	African clawed frog	SR	Meas	99.8%	4-d	24	Deformity	Embryo	17490	29100	22560	Schuytema & Nebeker 1998	A

Reasons for Exclusion

A. Less sensitive endpoint

B. Less sensitive life-stage

C. Test type not preferred (static vs. flow-through)

* SMCV calculated from 3 values

** SMCV calculated from 2 values

Table 9a. Excluded chronic plant toxicity data set for diuron of studies rated RL, LR, or LL. S: static; SR: static renewal; FT: flow-through. NR: not reported, n/a: not applicable; 95% CI: 95% confidence interval; SE: standard error.

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Achnanthes brevipes	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	24 (SE=1.0)	Hollister & Walsh 1973	LL 1, 2, 6
Amphora exigua	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	31 (SE=4)	Hollister & Walsh 1973	LL 1, 2, 6
Apium nodiflorum	Rooted macrophyte	S	Nom	> 99%	14-d	NR	Relative growth rate	Single stem node w/ leaf	0.05	NR	2.808	Lambert et al. 2006	LL 1, 5, 6
Apium nodiflorum	Rooted macrophyte	S	Nom	> 99%	14-d	NR	Growth inhibition (roots)	Single stem node w/ leaf	<0.0005	NR	0.00026	Lambert et al. 2006	LL 1, 5, 6, 7
Apium nodiflorum	Rooted macrophyte	S	Nom	> 99%	14-d	NR	Change in chlorophyll fluorescence ratio	Single stem node w/ leaf	5	NR	> 5.0	Lambert et al. 2006	LL 1, 5, 6
Chara vulgaris	Macrophytic alga	S	Nom	> 99%	14-d	NR	Relative growth rate	Terminal lengths of shoots w/ 3 nodes	0.0005	NR	0.35	Lambert et al. 2006	LL 1, 5, 6
Chara vulgaris	Macrophytic alga	S	Nom	> 99%	14-d	NR	Change in chlorophyll fluorescence ratio	Terminal lengths of shoots w/ 3 nodes	0.5	NR	4.033	Lambert et al. 2006	LL 1, 5, 6
Chlamydomonas sp.	Chlorophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	37 (SE=3)	Hollister & Walsh 1973	LL 1, 2, 6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Chlamydomonas sp.	Chlorophyceae family	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	10.8 (8.5-13.6)	Podola & Melkonian 2005	RL 1, 5, 8
Chlorella pyrenoidosa	Green algae	S	Nom	95.0%	4-d	25	Growth inhibition	Algal cells	NR	NR	25	Maule & Wright 1984	LR 1, 6
Chlorella pyrenoidosa	Green algae	S	Nom	50.0%	96-h	25	Growth inhibition	Algal cells	NR	NR	1.3	Ma et al. 2001, Ma 2002	LL 1, 3, 6
Chlorella sp.	Nonmotile unicell phytoplankton	S	Nom	Tech.	10-d	20.5	Growth inhibition	Algal cells	NR	NR	EC_{66}= 4	Ukeles 1962	LL 1, 2, 6
Chlorella sp.	Nonmotile unicell phytoplankton	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	19 (SE=2)	Hollister & Walsh 1973	LL 1, 2, 6
Chlorella vulgaris	Green algae	S	Nom	50.0%	96-h	25	Growth inhibition	Algal cells	NR	NR	4.3	Ma et al. 2002	LL 1, 3, 6
Chlorella vulgaris SAG211-11b	Green algae	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	27.4 (21.1-35.5)	Podola & Melkonian 2005	RL 1, 8
Chlorococcum sp.	Chlorophyte algae	S	Nom	Tech.	7-d	20	Growth inhibition	Algal cells	< 1.0	NR	EC_{62} = 10	Walsh & Grow 1971	RL 1, 2
Chlorococcum sp.	Chlorophyte algae	S	Nom	Tech.	10-d	20	Growth inhibition	Algal cells	NR	NR	10	Walsh 1972	RL 1, 2
Chlorococcum sp.	Chlorophyte algae	S	Nom	Tech.	90 min	20	Reduced Oxygen Evolution	Algal cells	NR	NR	20	Walsh 1972	RL 1, 2
Chlorococcum sp.	Chlorophyte algae	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	20 (SE=4)	Hollister & Walsh 1973	LL 1, 2, 6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Cyclotella nana	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	39 (SE=7)	Hollister & Walsh 1973	LL 1, 2, 6
Cryptomonas sp.	Algae	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	6.4 (5.3-7.8)	Podola & Melkonian 2005	RL 1, 5, 8
Dunaliella euchlora Lerche	Motile flagellate phytoplankton	S	Nom	Tech.	10-d	20.5	Growth inhibition	Algal cells	NR	NR	EC_{56}=0.4	Ukeles 1962	LL 1, 2, 6
Dunaliella tertiolecta	Green algae	S	Nom	99.0%	96-h	20	Growth inhibition	Algal cells	NR	NR	5.9	Gatidou & Thomaidis 2007	LL 2, 5
Dunaliella tertiolecta	Chlorophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	10 (SE=3)	Hollister & Walsh 1973	LL 1, 2, 6
Dunaliella tertiolecta Butcher	Green algae	S	Nom	Tech.	10-d	20	Growth inhibition	Algal cells	NR	NR	20	Walsh 1972	RL 1, 2
Dunaliella tertiolecta Butcher	Green algae	S	Nom	Tech.	90 min	20	Reduced Oxygen Evolution	Algal cells	NR	NR	10	Walsh 1972	RL 2, 6, 8
Eudorina elegans	Algae	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	13.2 (10.4-16.9)	Podola & Melkonian 2005	RL 1, 5, 8
Isochrysis galbana	Chrysophyte	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	10 (SE=3)	Hollister & Walsh 1973	LL 1, 2, 6
Isochrysis galbana Parke	Chrysophyte	S	Nom	Tech.	90 min	20	Reduced Oxygen Evolution	Algal cells	NR	NR	10	Walsh 1972	RL 1, 2, 8

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Isochrysis galbana Parke	Chrysophyte	S	Nom	Tech.	10-d	20	Growth inhibition	Algal cells	NR	NR	10	Walsh 1972	RL 1, 2
Lemna gibba G3	Duckweed	S	Nom	98.0%	7-d	25	Growth inhibition	NR	NR	NR	29 (27-31)	Okamura 2003	LR 6
Lemna minor	Duckweed	S	Nom	98.0%	48 h	21	Reduced oxygen evolution	Plant fronds	NR	5	NR	Eullaffroy et al. 2007	RL 1, 7
Lemna minor 1769	Duckweed	S	Nom	98.0%	7-d	25	Growth inhibition	NR	NR	NR	30 (28-31)	Okamura et al. 2003	LR 6
Monochrysis lutheri	Motile flagellate phytoplankton	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	18 (SE=3)	Hollister & Walsh 1973	LL 1, 2, 6
Monochrysis lutheri Droop	Motile flagellate phytoplankton	S	Nom	Tech.	10-d	20.5	Growth inhibition	Algal cells	NR	NR	EC_{100}= 0.02	Ukeles 1962	LL 1, 2, 6
Monochrysis lutheri Droop	Motile flagellate phytoplankton	S	Nom	Technical grade	10-d	20.5	Mortality	early instar	NR	NR	2500 (1000-5500)	Sanders 1970	LL 1, 5, 6
Myriophyllum spicatum	Rooted macrophyte	S	Nom	> 99%	14-d	NR (green house)	Relative growth rate	Terminal lengths of shoots w/ 3 nodes	0.0005	NR	5	Lambert et al. 2006	LL 1, 5, 6
Myriophyllum spicatum	Rooted macrophyte	S	Nom	> 99%	14-d	NR (green house)	Change in chlorophyll fluorescence ratio	Terminal lengths of shoots w/ 3 nodes	5	NR	> 5.0	Lambert et al. 2006	LL 1, 5, 6
Navicula forcipata	Diatom	S	Nom	99.0%	96-h	20	Growth inhibition	Algal cells	NR	NR	27	Gatidou and Thomaidis 2007	LL 2, 5
Navicula inserta	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	93 (SE=12)	Hollister & Walsh 1973	LL 1, 2, 6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Neochloris sp.	Chlorophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	28 (SE=5)	Hollister & Walsh 1973	LL 1, 2, 6
Nitzschia (Ind. 684)	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	169 (SE=17)	Hollister & Walsh 1973	LL 1, 2, 6
Nitzschia closterium	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	50 (SE=6)	Hollister & Walsh 1973	LL 1, 2, 6
Oscillatoria cf. chalybea	Cyanobacterium	S	Nom	80.0%	96-h	25	Growth inhibition	Algal cells	NR	280	28	Schrader et al. 1998	LR 1, 6
Phaeodactylum tricornutum	Chrysophyte	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	10 (SE=3)	Hollister & Walsh 1973	LL 1, 2, 6
Phaeodactylum tricornutum Bohlin	Chrysophyte	S	Nom	Tech.	90 min	20	Reduced Oxygen Evolution	Algal cells	NR	NR	10	Walsh 1972	RL 1, 2, 8
Phaeodactylum tricornutum Bohlin	Chrysophyte	S	Nom	Tech.	10-d	20	Growth inhibition	Algal cells	NR	NR	10	Walsh 1972	RL 1, 2
Phaeodactylum tricornutum Bohlin	Chrysophyte	S	Nom	Tech.	10-d	20.5	Growth inhibition	Algal cells	NR	NR	EC_{21}=0.4	Ukeles 1962	LL 1, 2, 6
Platymonas sp.	Chlorophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	7 (SE=3)	Hollister & Walsh 1973	LL 1, 2, 6
Porphyridium cruentum	Rhodophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	24 (SE=3)	Hollister & Walsh 1973	LL 1, 2, 6
Protcoccus sp.	Nonmotile unicell phytoplankton	S	Nom	Tech.	10-d	20.5	Growth inhibition	Algal cells	NR	NR	EC_{48}=0.02	Ukeles 1962	LL 1, 2, 6

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Pseudokirchneriella subcapitata (Selenastrum capricornutum)	Green algae	S	Nom	80.0%	96-h	25	Growth inhibition	Algal cells	NR	280	36.4	Schrader et al. 1998	LR 1, 6
Pseudokirchneriella subcapitata (Selenastrum capricornutum)	Green algae	S	Nom	98.0%	3-d	25	Growth inhibition	Algal cells	NR	NR	6.6 (5.9-7.2)	Okamura et al. 2003	LR 6
Pseudokirchneriella subcapitata (Selenastrum capricornutum)	Green algae	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	13.8 (9.3-20.4)	Podola & Melkonian 2005	RL 1, 8
Raphidocelis subcapitata	Green algae	S	Nom	50.0%	96-h	25	Growth inhibition	Algal cells	NR	NR	0.7	Ma et al. 2006	LL 3, 5, 6
Scenedesmus obliquus	Green algae	S	Nom	50.0%	96-h	25	Growth inhibition	Algal cells	NR	NR	4.09	Ma et al. 2002	LL 1, 3, 6
Scenedesmus obliquus	Green algae	S	Nom	98.0%	1 min	22	Change in chlorophyll fluorescence ratio	Algal cells	NR	NR	1†	Eullaffroy & Vernet 2003	RL 1, 4, 8
Scenedesmus quadricauda	Green algae	S	Nom	50.0%	96-h	25	Growth inhibition	Algal cells	NR	NR	2.7	Ma et al. 2003	LL 1, 3, 6
Scenedesmus subspicatus	Green algae	S	Nom	Tech.	24-h	20	Growth inhibition	Algal cells, 3-d old	4	NR	NR	Schafer et al. 1994	LR 5, 6
Scenedesmus subspicatus	Green algae	S	Nom	Tech.	72-h	20	Growth inhibition	Algal cells, 3-d old	10	NR	36	Schafer et al. 1994	LR 5, 6
Scherffelia dubia	Algae	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	3.9 (2.5-6.2)	Podola & Melkonian 2005	RL 1, 8

Species	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	EC_{50} (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Staurodesmus convergens	Algae	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	4.1 (2.5-6.9)	Podola & Melkonian 2005	RL 1, 5, 8
Stauroneis amphoroides	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	31 (SE=2)	Hollister & Walsh 1973	LL 1, 2, 6
Synechocystis sp.	Cyanobacterium	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	7.6 (5.5-10.5)	Podola & Melkonian 2005	RL 1, 5, 8
Tetraselmis elegans	Phytoplankton	S	Nom	99.8%	20 min	21.5	Change in chlorophyll fluorescence ratio	2-4 week old algal cells	0.1	0.5	3.0 (2.3-3.8)	Podola & Melkonian 2005	RL 1, 8
Thalassiosira fluviatilis	Bacillariophyceae family	S	Nom	Tech.	3-d	20	Reduced Oxygen Evolution	Algal cells	NR	NR	95 (SE=10)	Hollister & Walsh 1973	LL 1, 2, 6
Ulothrix fimbriata	Green algae	S	Nom	95.0%	7-d	25	Growth inhibition	Algal cells	NR	NR	540	Maule & Wright 1984	LR 1, 6

Exclusion Reasons
1. Not a standard method
2. Saltwater
3. Low chemical purity or purity not reported
4. Toxicity value not calculable
5. Control response not reported
6. Low reliability score
7. Endpoint not linked to growth, reproduction or survival (Ch. 3, Section 3-2.1.3)
8. Inappropriate test duration (Ch. 3, Section 3-2.1.1)

† Value reported as toxicity threshold, which is conceptually very similar to a MATC, but calculated differently than a MATC or an ECx value.
‡ Growth inhibition of roots is not a standard endpoint.

Table 9b. Excluded chronic animal toxicity data set for diuron of studies rated RL, LR, or LL. S: static; SR: static renewal; FT: flow-through. NR: not reported; 95% CI: 95% confidence interval.

Species	Common identifier	Test type	Meas /Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L) (95% CI)	Reference	Rating/ Reason for exclusion
Crassostrea virginica	Eastern oyster	FT	Meas	96.8%	96-h	23	Shell deposition	Neonates, <24-h	2400	NR	EC_{50}=4800 (4400-5200)	Ward & Boeri 1991	RL 2
Cyprinodon variegates	Sheepshead minnow	FT	Meas	96.8%	32-d	30	Mortality	< 24-h	1700	3600	2500	Ward & Boeri 1992a	RL 2
Mysidopsis bahia	Mysid	FT	Meas	96.8%	28-d	25.3	# of young surviving	< 24-h, juvenile	960	1900	1400	Ward & Boeri 1992b	RL 2
											LC_{50} (µg/L)		
Pimephales promelas	Fathead minnow	FT	Meas	98.6%	192-h	24.3	Mortality	30-d	NR	NR	7700 (pooled reps)	Call et al. 1983, 1987	RL 1, 5
Oncorhynchus mykiss	Rainbow Trout	S	Nom	95%	7-d	10	Mortality	juveniles, hatched <24h ago	NR	NR	74000 (29000-3681000)	Okamura et al. 2002	LR 1, 6
Oncorhynchus mykiss	Rainbow Trout	S	Nom	95%	14-d	10	Mortality	juveniles, hatched <24h ago	NR	NR	15000 (11000-29000)	Okamura et al. 2002	LR 1, 6
Oncorhynchus mykiss	Rainbow Trout	S	Nom	95%	21-d	10	Mortality	juveniles, hatched <24h ago	NR	NR	5900 (4700-7700)	Okamura et al. 2002	LR 1, 6
Oncorhynchus mykiss	Rainbow Trout	S	Nom	95%	28-d	10	Mortality	juveniles, hatched <24h ago	NR	NR	230 (8.9-590)	Okamura et al. 2002	LR 1, 6

Exclusion Reasons
1. Not a standard method
2. Saltwater
3. Low chemical purity or purity not reported
4. Toxicity value not calculable
5. Control response not reported
6. Low reliability score
7. Endpoint not linked to growth, reproduction or survival (Ch. 3, Section 3-2.1.3)
8. Inappropriate test duration (Ch. 3, Section 3-2.1.1)

Table 10. Acceptable multispecies field, semi-field, laboratory, microcosm, mesocosm studies; R= reliable; L= less reliable.

Reference	Habitat	Rating
Devilla *et al.* (2005)	Laboratory model ecosystem	L
Dorigo *et al.* (2007)	Lotic outdoor stream	L
Flum & Shannon (1987)	Laboratory microcosm	L
Hartgers *et al*. (1998)	Laboratory microcosm	R
Molander & Blanck (1992a)	Laboratory microcosm	L
Perschbacher & Ludwig (2004)	Outdoor pond	L
Pesce *et al.* (2006)	Laboratory microcosm	L
Sumpono *et al.* (2003)	Indoor pond	R
Tlili *et al*. (2008)	Laboratory microcosm	R
Zimba *et al.* (2002)	Outdoor pond	L

Table 11. Threatened, Endangered, or Rare Species Predicted values by ICE.

Surrogate		Predicted	
Species	**LC_{50} (mg/L)**	**Species**	**LC_{50} (mg/L)**
Rainbow trout (*Oncorhynchus mykiss)*	1.95	Chinook salmon *(O. tshawytscha)*	2.34
		Coho salmon (*O. kisutch)*	1.795
		Lahontan cutthroat trout (*O. clarki henshawi)*	0.753
Cutthroat trout (*O. clarki)*	1.4	Coho salmon (*O. kisutch)*	1.048